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FORESTS AND FLOODS

By WARD SHEPARD,[1] *Forest Inspector, Branch of Public Relations, Forest Service*

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FOREWORD

By WILLIAM B. GREELEY, formerly *Chief, Forest Service*

Now that the Mississippi floods have awakened us to the need for the most complete insurance possible against the recurrence of such catastrophes, it is essential that the true rôle of forests in flood control be recognized. Nothing will be gained by exaggerating the importance of that rôle. On the other hand, unless forests are permitted to play their part much will be lost.

Floods have been a common scourge of the world since legendary times. The Mississippi Valley experienced great overflows of water before its forests had been touched by an ax. Forests can not prevent floods in the face of heavy, long-continued rains or the rapid melting of masses of snow. To control the immense volumes of water suddenly flung upon the earth under such circumstances, in their rush to the sea, we must rely mainly upon the levee or reservoir or diversion channel.

But forests, well-sodded pastures, and terraced fields hold back more of the falling water and more of the soil than denuded woodlands, overgrazed hillsides, or eroded farms. This helpful influence can seldom be separated from the other factors affecting the flow of a stream so that it can be measured by itself in exact terms. It may be greater or less on a particular watershed, by reason of the soil, topography, or climate, but when exerted on all the watersheds of a great river basin it is enormous. Forests are better binders of the soil and better surface reservoirs of water than any other form of vegetation on the face of the earth; and the 160,000,000 acres of actual or potential forest land draining into the Mississippi have a real service to render in helping to protect the valley from destructive floods.

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[1] Resigned Mar. 31, 1930.

Behind the Mississippi and her tributaries lie 800,000,000 acres of land, acres on which the floods originate in falling rain or melting snow. The condition of these acres and the manner of their use can not but have a part in the speed and volume with which flood waters pour into the river channels. And behind the engineering structures upon which our main reliance for flood control must be placed should be created as much flood prevention at the source as can be brought about through better use of the land itself. More forests, more well-grassed pastures, and the holding of farm soil in place are desirable in themselves. They pay dividends on their own account, and flood control may be regarded as a by-product of other returns. This makes it all the more desirable that they should be included in our plans for the Mississippi.

This circular presents some of the chief facts on the relation of forests to stream flow and erosion, with a general outline of what, in the opinion of the Forest Service, forests can do to aid flood control. A more detailed forestry plan for the Mississippi Basin will be presented at the appropriate time, not as a panacea, but as part of the comprehensive program of flood control in which engineering, forestry, and agriculture should all have a share.

FORESTS AND FLOODS

The Mississippi disaster of 1927 has thrown into bold relief the need for national foresight in dealing with the perpetual menace of floods. Levees, reservoirs, and other structures for holding or diverting water always have been and always will be primary means of flood control; but indispensable as engineering works are to the harnessing of flood crests, they should be backed up by measures to reduce floods at their source, through the restoration of forests and grasslands as soil and water holders and the protection of farm lands from soil washing and gullying.

Excessive rainfall and sudden thaws will always cause floods in rivers unprotected by large natural reservoirs like the Great Lakes. The best of forests can not prevent the discharge of water into stream beds. It can slow down that discharge, however, and absorb a portion of it. Forest cover can not prevent the geological process of erosion. But it can prevent excessive man-made erosion that follows denudation or neglect of the soil.

The excessive silt load carried by so many of our rivers comes from the washing away of topsoils under unskillful methods of farming and grazing, from the gullying of worn-out or abandoned hillside farms, and from the erosion of forest soils after destructive logging or fire. Injury or destruction of the vegetative cover, whether grass or forest, and of its spongy leaf litter and vegetable mold (fig. 1), accelerate the run-off of rain and snow water. In large portions of the Mississippi Valley, once clothed with dense forests, a slow, inconspicuous, but immensely significant process has been going on for decades—the deterioration of the vegetative cover, the loss of leaf litter and humus, and the laying bare of mineral soil. From an increasing area of relatively barren and impervious soil, rain flows more swiftly and carries a greater load of silt that chokes river channels and raises flood crests. Water runs off a tin roof faster than off a straw stack. A bucket half full of water will overflow if filled with mud. These illustrations, exaggerated as they are, picture what happens on denuded and eroded slopes and in silt-laden streams.

The effect of the destruction of vegetation and humus seems insignificant on this or that acre, this or that farm, this or that stretch of woodland. But when we sum up the aggregate volume of erosion and run-off in an immense catchment basin, like that of the Mississippi, and compare this volume with the size of the stream channel that must carry the load of water and soil, we gain a new conception of the importance of surface conditions. Floods in large rivers begin as little drops of water and little grains of sand on millions of acres. Every tree, every bush, every fallen leaf, every blade of grass, every contour furrow, every ounce of porous topsoil that impedes the progress of these drops of water and grains of sand toward the main channel relieves the lower river of some of its load.

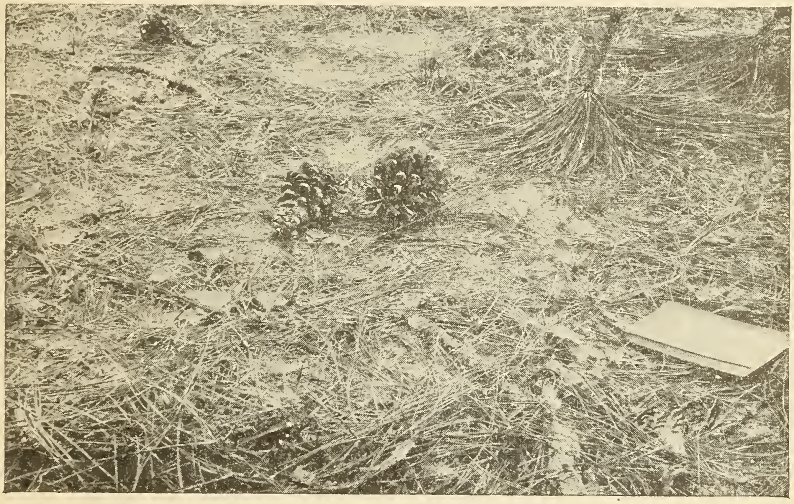

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Fig. 1.—In a well-kept forest the thick carpet of needles, leaves, twigs, and decaying wood protects the soil from erosion and acts as a sponge that carries rain water underground, where its passage to the springs and rivulets may require months. This delay prolongs and equalizes stream flow

The attack on floods should be a unified attack from the sources of the river to its mouth. There must be structures for controlling the water en masse, such as levees, reservoirs, and spillways; but the full measure of protection demands well-kept forests, grasslands, and fields to aid in controlling water before it is massed and concentrated. Proper use of the land surface of a great watershed will not only reduce the violence of floods but will protect the engineering works themselves from injury by heavy deposits of silt. It is even more important as a means of safeguarding life-giving soil from wastage and sterility. The best of all soil holders is the forest; it is the most absorptive form of vegetative cover; and it yields a crop adapted to the steeper and rougher lands where erosion and run-off are most rapid and a protective cover of the soil is most needed.

Forests are simply one of the influences affecting the behavior of streams, an influence which may be greater or less in the composite of all the conditions which have to do with the volume and rate of run-off. The precise effect that a given area of forest within a large watershed has upon the discharge into the river can not be determined because so many other factors influence the behavior of streams. One of these factors is the presence or absence of natural reservoirs in the form of lakes and swamps. The St. Lawrence, for instance, is regarded as one of the best-regulated rivers in the world because of the storage system afforded by the Great Lakes. Other factors are the steepness of the slopes, the porosity of the rock and soil, and the nature of the climate. The severity of the Mississippi flood in 1927, for example, was due to a climatic factor, heavy and long-continued rains in the lower portions of the valley. It would be fruitless and shortsighted to exaggerate the effect of forests upon river systems. They are simply one of the beneficial influences that can be brought into play.

The prevention of staggering losses of life and property from flood crests is the primary purpose of river control. But more than that is at stake. Holding soil in place and preserving its fertility, protecting bottom lands back on the small tributaries, and maintaining more regular flow in the feeder streams for the many resulting economic benefits are all objects that should be sought. For some of these protective purposes, forests and other forms of vegetative cover are the only possible means, and through their aggregate effect on all the feeder streams they have an ameliorating influence on the large floods in main rivers. Along with this protecting and ameliorating influence on water flow, forests more than pay their own way by producing marketable crops on land not fit for fields or pastures.

The following discussion of the influence of forests on run-off and erosion is drawn from experience and observations at many widely scattered points, and is designed to sketch a general picture of the relation of forests and other forms of surface protection to run-off and erosion in helping to provide flood protection.[1]

FOREST, SOIL, AND WATER

In building up a true conception of the influence of forests on a great river system one can best begin by drawing a simple picture of running water at work on a limited plot of ground, then enlarging this picture to cover minor valleys, and finally multiplying it a thousand or a million fold to attempt some measure of the immense cumulative effect of the destructive forces that are unleashed by abuse of the soil and its natural cover.

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[1] The following publications have been drawn upon for examples and data, and the reader is referred to them for more detailed discussions of forests, run-off, and erosion:

ASHE, W. W. FINANCIAL LIMITATION IN THE EMPLOYMENT OF FOREST COVER IN PROTECTING RESERVOIRS. U. S. Dept. Agr. Bul. 1430. 35 p. illus. 1926.

MUNNS, E. N. EROSION AND FLOOD PROBLEMS IN CALIFORNIA. Calif. State Bd. of For. Rpt. to legislature of 1921 on Senate Concurrent Res. No. 27.

ZON, RAPHAEL. FORESTS AND WATER IN THE LIGHT OF SCIENTIFIC INVESTIGATION. Final Rpt. Nat. Waterways Com., App. V. Sen. Doc. 469, 62d Cong., 2d sess. 1912. A reprint of this report may be obtained, as long as the supply lasts, by applying to the Forest Service, Washington, D. C.

THE FOREST AS A SOIL HOLDER

In watering a lawn one can see how the water trickles along the ground, collides with grass blades, splits up into tiny rivulets, spreads out slowly, and remains clear until it sinks into the soil. The same water falling on bare soil (unless it is absolutely level) gathers headway, collects rapidly in little rills and streams, and with its growing speed and concentration begins to tear loose the finer particles of soil, then sand, and, finally, gravel. Where its speed is checked, the turbid rivulet deposits its load; if it still gathers speed and volume it begins to cut a gully, its load of sand and gravel acting as an abrasive to cut faster and deeper.

This example shows in miniature how vegetation protects the soil and how the absence of vegetation permits soil to be easily carried away.[2] Vegetation hinders the flow of water, and by spreading it out takes away its force. Thus checked, it can not dislodge the soil particles, which, moreover, are bound together by the tangle of roots. Without vegetation there is nothing but the friction of the soil to keep water from following its inherent habit of going downhill as fast as it can. The cutting power of running water and its ability to transport soil increase greatly with increased speed. After the vegetative cover is removed, rain and sun compact the soil, each succeeding rain makes new gullies or deepens old ones, and the destructive combination of speed and concentration gains headway.

A well-kept forest is the best of natural soil holders. It has a dense ground cover of trees, shrubs, and lesser plants that impedes the flow of water. Tree roots spread far and wide to a depth of 2 feet or more, usually much deeper than the roots of grass or farm crops; and the roots of the lesser plants help to bind the topsoil together. On top of the ground is a mat of leaves or needles, twigs, branches, and dead grass and herbs, varying from a few inches to a foot or more in depth; and beneath this mat is the spongy woods mold or humus derived from the decay of generations of leaf fall. (Fig. 2.)

The canopy of leaves and branches breaks the force of rain and evaporates considerable quantities of it. The rain that penetrates the canopy has next to contend with the leaf litter, which retards the water in its flow over the surface, soaks up part of it, and passes part of it down to the humus and thence into the mineral soil. Also in their life processes, trees absorb large quantities of water from the ground and pass it off as vapor from their leaves. By these means the forest intercepts and evaporates a part of the rainfall, absorbs another part, and slows down the surface flow of the rest, retarding its speed and erosive action on the soil. Even in heavy rains the soil under a dense well-kept forest is little disturbed, and the streams that derive their water from such a forest are likely to remain clear.

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[2] A test made by the Missouri Agricultural Experiment Station showed that during six years erosion had removed soil at the rate of 208 tons per acre from bare uncultivated land, as compared with less than 2 tons per acre from similar land covered with bluegrass sod; in other words, one hundred and twenty-two times as much. See DULEY, F. L., and MILLER, M. F. EROSION AND SURFACE RUN-OFF UNDER DIFFERENT SOIL CONDITIONS. Mo. Agr. Expt. Sta. Res. Bul. 63. 1923.

THE FOREST AS A WATER HOLDER

The things that make the forest a good soil holder also make it a good water holder. During a rain the flow of surface water is retarded. More of it has a chance to sink down into the absorptive leaf litter, thence into the decayed leaf mold, and so down into the mineral soil and the fissures of the rocks. There it joins the great reservoir of underground water that feeds springs, brooks, and rivers. The deep, tangled root system of a well-kept forest also greatly aids this process of seepage, for water flows along living roots or through the tubes formed by decayed roots, far down into the soil.

Under ordinary conditions forest soils absorb from 20 to 50 per cent of light or moderate rains. Even in a prolonged rain the leaf mulch keeps feeding the water underground and thus empties and refills itself. In a violent or long-continued rain so much water may fall as to overtax this absorptive capacity, but even so, the forest has already reduced the run-off and continues to impede the remaining surface water in its progress to the stream beds. Such torrents as rush from bare, gullied land are rare in a forest, where during even a heavy rain one always has a sense of the dripping of water rather than of a rapid rush.

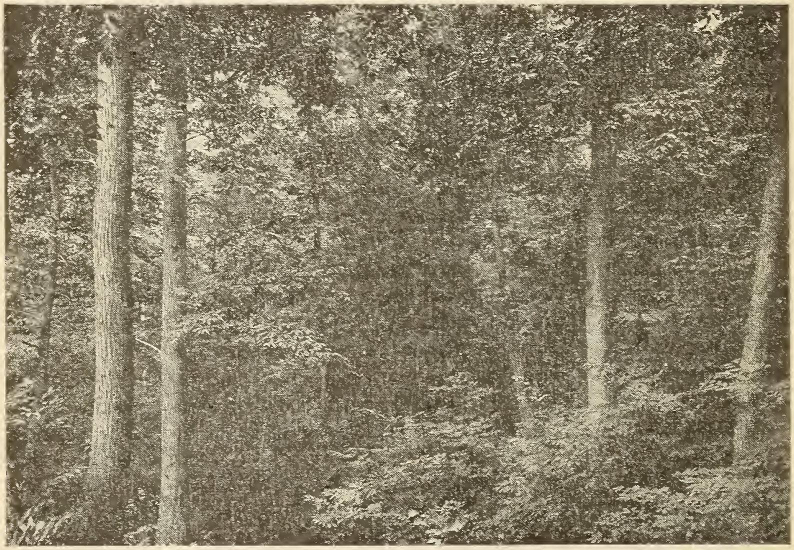

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FIG. 2.—A forest is the best vegetative cover for holding soil and water. The canopy of leaves and branches catches and evaporates a great deal of rain. What drips to the ground is impeded by the dense cover of shrubs, ferns, fallen leaves, and decaying wood, which absorbs much water underground, slows down the run-off, and keeps the soil from being washed into the streams

Underground storage of water by forests is an important natural means of regulating and equalizing stream flow. The immense quantity of water carried into the earth by the absorbent ground cover of a forest may percolate for months before it emerges.

Humus and leaf litter, while thus acting directly as an absorbent, also keep the soil itself mellow, porous, and more permeable. Forest soil is softer, lighter even than newly plowed loam. Forest humus does double duty to mankind. It leads water underground and it feeds the growing trees. It is a natural asset of incalculable value.

A forest has still other means of retarding run-off. Water and snow, falling on the leaves and branches of trees, are either evaporated or delayed in reaching the ground. The water evaporated may be as much as one-third of the total precipitation. More important, however, is the influence of forests in retarding snow melting. A well-stocked forest moderates the extremes of temperature; it is warmer in winter and cooler in summer than open land. As spring comes on, snow melting may begin earlier in the woods, but it usually lasts from four to eight times longer than on open ground. Moreover, as the mellow soil of a forest is likely to remain unfrozen or to freeze less deeply than soil in the open, it absorbs more of the snow water; soil in the open, freezing more freely and deeply during winter, permits snow water to rush off more rapidly into the streams. Spring freshets from melting snow are an important source of river floods. By delaying snow melting, feeding part of the snow water into the ground, and thus prolonging the period of run-off, forests tend to reduce flood crests and to equalize stream flow.

DEFORESTATION AND EROSION

Normal erosion is a geological process, and as long as water flows over the surface of the land it will continue its ceaseless work of carrying the mountains down to the sea. But with her kindly mantle of forest and grass nature protects the land from the gnawing tooth of running water, makes the soil fertile and life-giving, and restrains the levelling of the hills to an orderly and imperceptible process.[3]

Abnormal erosion as a man-made process is very different. When the soil-binding plant cover is broken, the earth is exposed to the insatiable cutting power of water. In this day of the steam shovel, one can easily observe abnormal erosion at work in fresh cuts, fills, and embankments. Until vegetation reclothes the soil, every violent rainstorm washes quantities of mud into the streets, sewers, and drainages; but from grass lawns near by only clear water flows.

Erosion can often be observed on abandoned farm land. If the ground is level, the insidious effects of "sheet" erosion are not very obvious; but if the ground slopes even a little the erosive action of water leaves a striking mark. Most of the water, instead of sinking in or trickling over the surface, rushes swiftly down the old furrows or makes little gullies of its own. Gathering speed and force, it rapidly cuts deeper and carries an ever-increasing load of soil.

In denuded or depleted forests[4] a similar but less obvious process goes on. It is less obvious because most denuded forests reestablish on the land a vegetative cover of some sort. But such areas, unless protected from fire and promptly restocked with young trees, lose much of their value as holders of water and soil. In the fire-swept denuded forest, the mineral soil, already scarred and broken by logging, becomes more and more exposed to the erosive force of water. (Fig. 3.) Fire consumes the logging débris and the protecting cover of leaf litter and humus, weakens and thins out the soil-binding grass and other vegetation, and by impoverishing the soil and exposing it to packing and drying reduces the chance of reestablishing a denser cover. Ravines are apt to form in the old logging roads. Gullies eat back into the bare slopes. The exposed surface is washed by every rain. A balance of nature that had existed for ages is overthrown and the soil of the hills takes its way to the sea. If fire is kept out, however, so that shrubs, briars, weeds, or young trees spring up in abundance, the natural protection from erosion afforded by a cover of forest may gradually be restored.

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[3] Normal erosion is described here in its most common and usual form. There are, of course, numerous instances of violent and destructive erosion, as in the case of cloudbursts or landslides, which are due wholly or primarily to natural causes.

[4] In this discussion, the terms "forest denudation" and "deforestation" are applied to methods of cutting timber, often accompanied by fire, which largely destroy a forest cover and prevent its replacement for a long period of time.

It is not necessary to remove all of a forest to accelerate erosion. Forests that have been repeatedly burned and badly thinned, but that are clothed with green foliage, may have the appearance of being uninjured. Even a fire that kills no mature trees almost uniformly destroys the underbrush, grass, and leaf mulch, and bares the mineral soil. Farm woodlands are frequently not only burned but overpastured. Such disturbances of the plant cover invite erosion in proportion to their intensity.

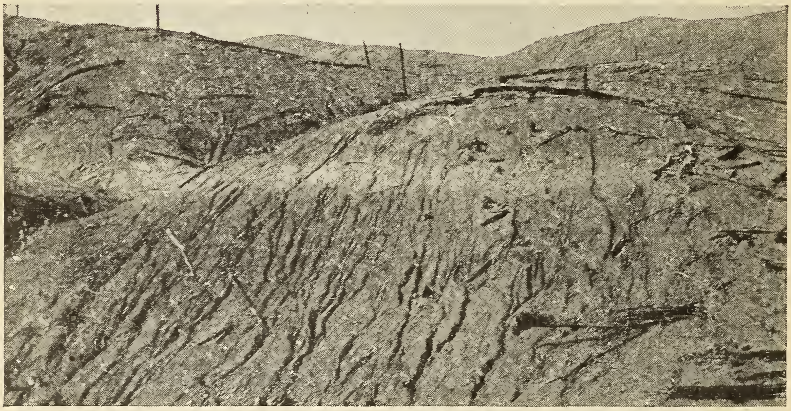

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FIG. 3.—When the forest is destroyed by logging or fire, the soil, no longer protected by the mat of decaying leaves and wood, is swiftly gullied by rains. Water rushes off the slopes in torrents, filling the streams and raising their flood crests with a heavy load of soil

A type of erosion that is hastened by deforestation is the caving of stream banks where trees have been cut away. The tangled roots of willows, alders, birches, cottonwoods, and other trees and shrubs growing along streams bind the soil of the banks and weaken the cutting power of the current. As a result, well-wooded streams usually flow in clean-cut, narrow channels, whereas deforested streams are apt to eat into the banks, wash the soil into the channel, and form a wide, shallow, meandering bed. (Fig. 4.)

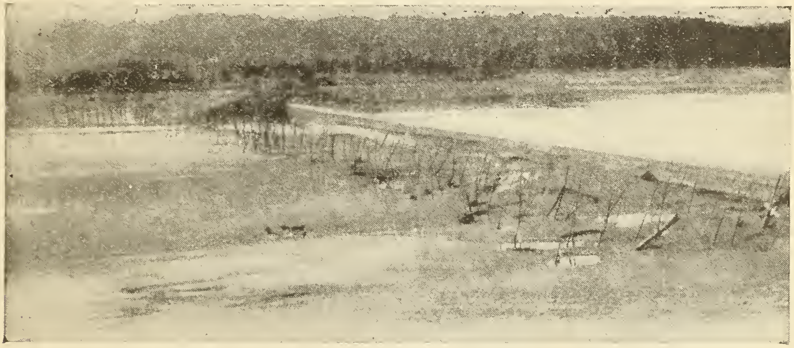
Erosion as a result of the destruction of vegetation cover is not confined to forests. In the grasslands of many portions of the Great Plains thinning and deterioration of the vegetation have been going on for decades. The cause is overgrazing, but the effects on soil and stream flow are essentially the same as the effects of deforestation, though less pronounced.

EXAMPLES OF EROSION

The striking increase of erosion on watersheds that have been deforested has been observed frequently both in America and in Europe. It can best be studied in small valleys, for there the contributing factors are more easily observed and weighed than in large drainages.

In 1913 fire destroyed the brush cover on a small branch of the Los Angeles River in the mountains of southern California. Careful study led to the conclusion that in the year following the fire 100,000 cubic yards of soil had been washed from an area of 1.2 square miles.

The soil that was washed from a burned hillside of 200 acres in San Diego County, Calif., buried a 12-acre alfalfa field so deeply that no signs of cultivation remained.



(Photo by Thorndyke Saville, North Carolina, Geological and Economic Survey)

FIG. 4.—The evil of soil erosion extends down to the main streams, where it clogs the channels, cuts down the carrying capacity, and impairs flood-control works. This reservoir, formed by a 38-foot dam built as recently as 1910, has been made useless by silt. Top soil to the amount of 126,000,000,000 pounds is swept into our rivers each year from poorly handled farms, grazing lands, and forests

On a tributary of the Sacramento River, where vegetation was killed by smelter fumes, as much as 400 cubic yards of soil per acre has since been removed by erosion.

A flood in a deforested canyon in California carried from twenty to forty times as much sediment as the coresponding freshet in an adjoining forested canyon, and continued muddy after the other streams had cleared.

The effects of denudation of grasslands at high altitudes in the Wasatch Mountains of Utah have been studied by the Forest Service. On a small, badly overgrazed watershed, rainfall, run-off, and erosion were accurately measured for a number of years. Grazing was then excluded and the vegetation allowed to increase to about two and one-half times its previous density. This increase in density decreased erosion by 56 per cent. One storm in the first period washed down 2,354 cubic feet of sediment; a storm of equal intensity and greater duration in the later period washed down only 845 cubic feet of sediment.

Similar examples of erosion following denudation could be cited from other parts of the United States, particularly the southern Appalachian Mountains, and from many other parts of the world. Such erosion has been especially severe in parts of France, Italy, Spain, Greece, Asia Minor, and China.

DEFORESTATION AND RUN-OFF

The swift run-off that follows forest destruction raises the flood level with silt, gravel, and bowlders. It also raises the flood level with an excess burden of water that would under normal conditions be absorbed into the ground. The reduction of this surplus burden of silt and water is a prime objective of flood control.

The influence of deforestation in speeding up run-off has been accurately observed and measured in small valleys. One of the most famous of these experiments was carried on for many years at Emmenthal, in Switzerland, where the run-off from two small valleys, one completely forested, the other only partially forested, was measured and compared. It was found that the stream from the completely forested valley was more uniform in its flow and carried less débris than the other stream. After very heavy rainfall of brief duration the forested stream carried only from a half to a third as much water as the partially forested stream. In the summer the forested stream kept up a higher and more regular flow.

The burning of the brush cover in a small canyon in southern California has already been mentioned. After a heavy rain the following winter the run-off from this canyon exceeded that from any other stream which experienced the same storm. Its flood peak reached the unprecedented flow of 700 second-feet per square mile of catchment area.

Several years ago a disastrous flood was caused at Pueblo, Colo., by local cloud-bursts. In canyons that had been largely denuded, the crest of the flood occurred six hours after the beginning of the storm. In the forested canyons the flood crest occurred from 18 to 48 hours after the beginning of the storm and caused much less damage.

That such effects come in part from destroying the absorptive capacity of the forest floor is shown by experiments made by the Forest Service in the mountains of southern California. Within three years after the brush cover on a canyon drainage was destroyed by fire the soil had lost 45 per cent of its water-absorbing power. This loss was due partly to the burning of the litter and humus and partly to the rapid erosion of the topsoil.

The Missouri Agricultural Experiment Station has shown that over a period of six years nearly half the rain falling on a plot of bare uncultivated soil ran directly off into the streams, whereas only a little more than one-tenth of the rainfall ran directly off similar soil covered with bluegrass sod.

In the Forest Service experiments in the Wasatch Mountains an increase of two and one-half times in the density of the grass cover decreased the surface run-off 55 per cent, even though at its densest the grass was less than half of a full cover. From one storm during the early period of scanty cover the surface run-off from the small watershed under observation amounted to more than 15,000 cubic feet; whereas in the later period of denser cover, from a storm of greater duration but equal intensity, the surface run-off was less than 6,000 cubic feet, or 39 per cent as much.

The influence of deforestation in drying up springs is widely established by authoritative examples both in America and in Europe. Springs form a striking and common evidence of the presence of underground water, which is the principal contribution of forests in equalizing and prolonging the flow of streams. The disappearance of springs after deforestation is ordinarily proof that rainfall has run more rapidly from the denuded surface instead of sinking into the ground.

CUMULATIVE EFFECTS OF DEFORESTATION ON LARGE RIVERS

The examples cited indicate the effects of deforestation on small watersheds. It is frequently asserted that deforestation has no influence on large rivers because great floods occurred before the forests had been touched by the ax. At the opposite extreme, it is asserted that floods are due primarily to deforestation. It is necessary to use moderation and common sense in approaching this problem. Forests can not prevent the great floods that come from heavy, long continued, widespread rains, especially when combined with the rapid melting of snow. On the other hand, both common-sense observation and careful study have shown that forests may reduce the violence of floods and erosion not only in small watersheds but in large river systems.

The difficulty of "proving the case" by exact measurement arises in part from the impossibility of weighing each of the complex factors that influence the behavior of a large river, such as varying conditions of soil, slope, vegetation, cultivation, and climate as well as natural storage in lakes, swamps, and overflow lands. In the absence of exact quantitative proof, we find it difficult to visualize the cumulative influence of thousands of square miles of distant and perhaps scattered forests on the main river channel where the flood rages. When we visualize the forest, we think of an acre or a few acres, and we ask how such a limited surface reservoir can have any measurable effect on the giant flood that is bursting the dikes of the river. How much can it hold back from the torrent? What relation can its steadily flowing springs, rivulets, and brooks have to the great flood?

The answer is to be found in the vast extent of the forest reservoir as compared to the relatively narrow channel in which the mightiest river is confined, especially if it has been pinched between levees. It is like an enormous roof drained by a single waterspout. The forests of a great river basin constitute, it is true, only a shallow reservoir but one that may make up for its shallowness by its extent. If these forests are in good condition, they hold the soil in place; they carry a large proportion of their water underground, pay it out slowly through springs and rivulets, and thus hold back the flood stages of countless brooks, creeks, and little rivers. Now, it is precisely these springs and rivulets, brooks and small rivers that feed the main rivers. From direct rainfall on their surface and from the run-off of their immediate banks the large rivers receive only an insignificant fraction of their water. The greatest rivers and the most violent floods merely collect and concentrate in one channel the individual contributions of innumerable minor and individually unimportant streams. And these minor streams are in turn merely collectors of water from the vast unchanneled surfaces they drain. On these surfaces the potential rivers and floods fall as drops of water whose cumulative effect depends on the speed they gather on their way to the sea. The physical condition of every square foot of the great aggregate of these land surfaces determines in some measure whether run-off is to be held back or speeded up, and it is here that an important key to flood reduction is found; for vegetative cover, if vigorous and dense, checks water as it falls and while it is still spread in harmless quantities over great areas. During this period, while water is "mobilizing" for its assault on main-stream channels and before it has concentrated in large masses and attained dangerous speed, vegetative cover may exert a decisive influence on flood stages by capturing a considerable part of the water and holding it back even if for only a short period. (Fig. 5.)

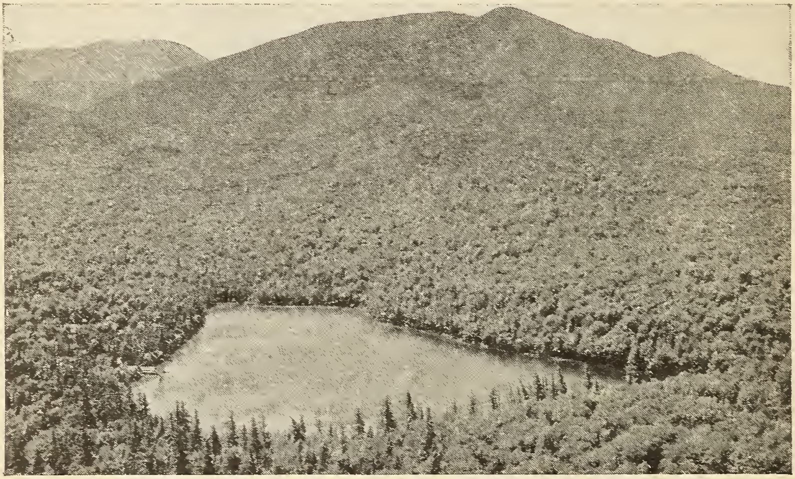


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Fig. 5.—The forest is only a shallow reservoir; its power lies in its vast extent. The amount of water and soil that any acre of forest holds back from the stream seems insignificant when we think of a great flood. But we must multiply that acre by millions to get some conception of the importance of forest cover on a great river basin

The relative effect of forests or other vegetative cover may be greater or less in comparison with the many other factors influencing the speed with which rainfall concentrates in the major river channels. It is relatively unimportant in regions composed of sand plains and gravel beds or strewn with lakes and swamps. It is much more important in regions of steep topography and impermeable soils. The examples cited of the effects of deforestation on small streams are drawn from regions with soils and topography of the latter kind. Similar results on a larger scale necessarily follow the destruction of forest cover on extensive watersheds with similar soil and topography.

We are not forced even here, however, to rely on speculation or theory. There is ample testimony from Europe, from Asia, and from America that large rivers have markedly changed their habits and that this change has been for the most part in the direction of higher and more violent floods, of lower water in dry seasons, and of the choking of channels with débris. This testimony is not made up of the vague impressions of old men. It is confirmed by the study and observation of scientists and engineers, and has been an object of interest to scientific academies, engineering congresses, governments, and parliaments in various countries.

In the absence of marked climatic or geological changes, the cause of these disturbances of river flow can be ascribed only to changes in surface conditions that increase surface run-off and erosion. In modern times the most striking change that man has wrought over great areas of the earth's surface is the destruction of forests. This destruction has been extremely rapid in the United States during the last 50 years. In recent decades, with the rising value of timber, destructive lumbering has advanced far into rough, mountainous country, where the effects of denudation are most severe. It must be then that the widely attested deterioration of large rivers is related to the deterioration of the forests that once densely clothed their slopes and headwaters, though other factors have, of course, been brought into play, like the augmentation of run-off through the ditching and tiling of wet lands.

Let us examine a little of the evidence. M. O. Leighton, chief hydrographer of the United States Geological Survey, made a careful study of flood and rainfall records for the period 1885 to 1907 on the Ohio River and three of its tributaries, on the Wateree, the Savannah, the Tennessee, and the Alabama Rivers in the South, and on the Connecticut River in New England. The method used was to determine for each year the number of days of flood stage in proportion to precipitation.[5] The most marked change was found on the Ohio, whose flood stages in proportion to precipitation increased from 0.38 in the period 1885–1895 to 1.48 in the period 1896–1907. All the rivers studied showed an increase of flood stages. A specially intensive study of the Tennessee River over a 24-year period showed that flood stages in the latter half of the period, compared with the number of days of rainstorms heavy enough to produce floods, increased nearly 20 per cent.

A survey and historical study of the Delaware River between Trenton, N. J., and Easton, Pa., showed that previous to 1835 floods of 14 feet at Lambertville had been recorded only three times, whereas after 1835 floods of that height became common and in at least three instances exceeded that height by a third to a half.

An investigation, the results of which were published in 1899, showed that the Genesee River, in New York, whose watershed was entirely deforested, had a maximum rate of flow three times as great as that of the Hudson, whose watershed was 90 per cent forested, and a minimum rate of flow only about one-fourth as great. In other words, its flood stages were violent and its low water stages abnormally depressed.

The effects of erosion in silting large river channels have been even more widely observed. Only a few examples will be cited.

The amount of sediment carried by the Susquehanna River had become so great by 1871 that the Brewerton Channel to Baltimore was obstructed and had to be abandoned.

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[5] C. F. Marvin, Chief of the Weather Bureau, states that this method does not take into account certain factors influencing floods, namely, the duration of precipitation and its local distribution, as well as the intervals of one or more days between consecutive heavy rainstorms during flood periods.

Forty years ago the Coldwater River, in Mississippi, was regularly navigated by large boats, which loaded cotton at the town of Coldwater. Mud flats and sand bars have closed this portion of the river to navigation.

The Tennessee River carries an annual silt burden of 11,000,000 tons; yet some of its heavily forested head streams carry only a trace of silt even in high water. The Tennessee gathers its soil burden mainly from deforested and agricultural lands.

Numerous examples could be cited from Europe. A government survey of the River Po showed that floods had steadily increased in height for a century. The Loire was formerly much used for navigation. Now it is no longer navigable above Saumur. Its bed is choked with sediment and in summer is only a great stretch of sand. After a storm or a sudden thaw "every depression in the ground gathers a torrent, every ravine confines a river, and all these waters, accumulating in the valley of the Loire, form a roaring sea." The forests of the Loire watershed have been reduced until they cover only 13 per cent of its area.

The effects of rapid run-off and erosion, multiplying as the headwaters converge, extend downstream into the large rivers, increasing their burden of water and detritus, concentrating their task of transportation into a shorter period, and decreasing the capacity of the channels by silting.

Silting has another important bearing on floods; it is a menace to the engineering works used in river control. Silting reduces the storage capacity of reservoirs built for flood retention and may ultimately fill them. The reduction of erosion simplifies the flood-control problem from whatever angle we view it.

SOIL WASTAGE

Although this discussion deals primarily with forest land, a brief consideration of farm and grasslands will round out the conception of rational land use as a part of a comprehensive plan for the control of floods, and it will be of timely interest to consider such a plan chiefly on the basis of the history and condition of the grasslands, farming areas, and forest lands of the Mississippi Basin.

WESTERN GRAZING LANDS

The Mississippi receives about one-sixth of its flow of water from the eastern slopes of the Rocky Mountains and the Great Plains. The headwaters of these tributaries are mainly clear, for they are partly forested and are fed chiefly by springs and melting snow. But on their course through the plains they are subject to violent fluctuations between high and low water stages, their banks suffer constant undercutting, and their meandering channels are clogged with silt and sand bars. The Missouri River above Ruegg, Mo., carries a yearly load of 176,000,000 tons of silt.

In the drainage basins of these western tributaries there are 25,000,000 acres of unreserved public domain, on which the Government has allowed free and unrestricted grazing. Excessive grazing on many areas has impaired the ground cover in quality and density. An experiment made by the Forest Service on open grasslands in Utah showed that the run-off from rainstorms on overgrazed land was seven times as great as that on moderately grazed lands. In the national forests, grazing control has as one of its aims the reduction of erosion and flood discharge. The Secretary of the Interior has recommended that similar grazing control be extended to the unreserved public domain. Building up the herbaceous cover in order to armeliorate floods and silting is an important phase of grazing control.

FARM LANDS

The erosion of cultivated farms and pastures is going on in the United States at an alarming rate. From hundreds of thousands of acres in western Kentucky, Tennessee, and Mississippi, northeastern Kansas, and other hilly regions, the best soil has been carried away. A survey of one county in the Piedmont region revealed over 90,000 acres of once productive land degraded to gullies and bare rock. In the central Appalachians it is estimated that 50 per cent of the cleared land has been seriously damaged by erosion. On the steeper slopes, many old fields have been washed down to bedrock or sterile subsoil. In many parts of the country thin soil overlying bedrock has been ruined or impoverished by poor cultivation.

This wastage of life-giving plant food by the "sheet" erosion of our best soils and by the unwise cultivation of steep slopes is a direct economic loss of incalculable magnitude. Our present concern, however, is with its effects on stream flow. This immense burden of silt has had a large part in clogging river channels and adding to the height of floods. Its removal has exposed the less permeable subsoil and speeded up the rate of run-off, a vital factor in floods.

The cure of this evil can come only from such measures as terracing, contour plowing, careful pasturing, the improvement of farm woodlands, and planting steep, denuded slopes to trees or grass. As one soils expert has expressed it, some soils "melt like sugar" when cleared, even on gentle slopes, and should never be cleared at all. Slopes of easily eroded soils should be kept in forest or pasture. The encouragement of such protective measures is a matter for the agricultural experts of the Federal and State Governments.

FOREST LAND

The clearing of forests for cultivation is an inevitable part of advancing civilization. No one could object to the hewing of farms from the primeval wilderness. But such purposeful clearing must be distinguished from the denudation that results from fire or destructive lumbering and burdens the Nation with large quantities of idle or half-productive forest land not needed or used for farming.

Up to about 1880 the need for more farm land in the United States kept pace with forest destruction. Then, with the expansion of lumbering, forest destruction began rapidly to outpace the rate at which the cleared land could be used for farms. All told about 200,000,000 acres of forest land has been cleared primarily for tillage and about 75,000,000 acres more of land logged for its timber has been converted into fields. But in addition a vast area of logged-off land, estimated at over 330,000,000 acres, has never been put under the plow or has been abandoned after a period of cultivation. Most of this land is either too rough or too sterile for farming. Of this cut-over area some 80,000,000 acres is now classed as denuded land, with little or no forest cover; while the rest bears culled forest, second growth, or young trees and sprouts, often inferior in quality and in the density of the stand.

Forest destruction is not an inevitable part of lumbering, although one has largely gone with the other in the United States. It results from the removal of timber with no provision for replacement, from neglect of cut-over land, and particularly from repeated fires in slashings and logged-off areas. The practice of forestry, on the other hand, often removes but a portion of the timber, leaving the smaller trees for further growth; or, if clean cutting is advisable, insures prompt reforestation through natural seeding or planting.

The harvesting of timber under practicable methods often requires a temporary impairment of the water-holding capacity of a forest, but this is speedily restored if reforestation is prompt and vigorous. The forestry policies of Europe long have recognized the need for "protection forests" on high, steep mountain slopes forming the headwaters of important rivers. Cutting in such forests is conducted with extreme care or not permitted at all in order to avoid impairing the effectiveness of the forest cover for retarding run-off and erosion. The ownership and maintenance of protection forests are commonly regarded in the Old World as public functions; and the same conception has been carried into the purposes and administration of national forests in the United States. It is one of the objects sought by the Weeks Act of 1911 for protecting the headwaters of navigable streams.

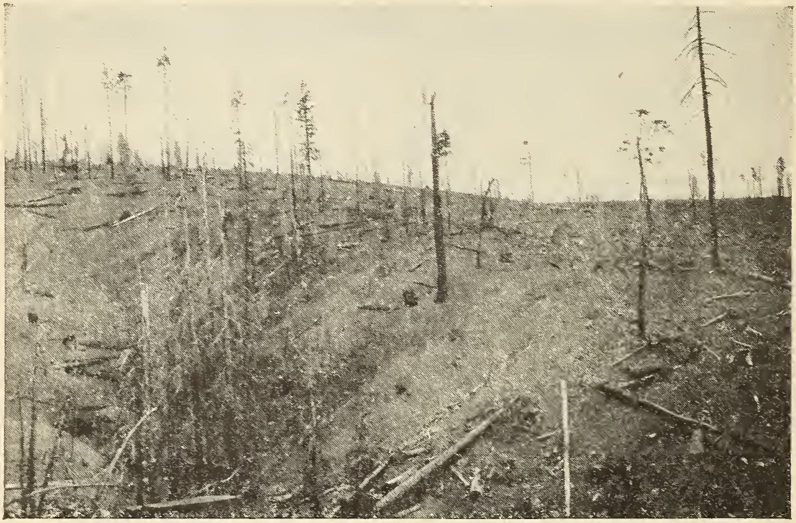

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FIG. 6.—The clearing of fertile lands for farms has been inevitable and desirable. Forest denudation is a different story. In the United States we have about 80,000,000 acres of denuded forest unsuited to agriculture and over 200,000,000 acres of second-growth forest, much of it inferior and poorly cared for. Very little of this land is rendering its full service in timber growing, water storage, or soil holding. The first step in forest rehabilitation is universal protection against fire

Much of our second-growth forest is deteriorating by reason of repeated fires and the cutting of smaller and smaller timber. Notwithstanding the progress that has been made in farm forestry and industrial forestry, especially in protecting woodlands from fire, a large part of our forests come nowhere near exerting to the full their potential power for timber growing, soil holding, or water absorption. If our forest lands are to render their full economic service, including soil and water conservation, they must be devoted to more intensive timber culture. Also much of the abandoned and marginal farm land, which is now a drag on agriculture, must be converted to forest.

Though much of the forest in the Mississippi Basin was inevitably cleared for farms, there remain extensive areas of forest land, widely varying in cover and condition, that have a bearing on the flood problem. The most important of these areas will be briefly considered.

MINNESOTA AND WISCONSIN FORESTS

The headwaters of the Mississippi River find their source in what was once a part of the great lumbering regions of Minnesota and Wisconsin. Much of the soil is sand and gravel which absorb water readily even after the forest cover is destroyed. Moreover, the land is level or gently sloping, and the headwaters of the Mississippi have an extensive lake and swamp system with a large capacity for storing flood waters. About 50 miles below St. Paul the river widens into what is known as Lake Pepin, which acts both as a settling basin and a regulator of stream flow. The tributaries emptying into the Mississippi below Lake Pepin are heavily burdened with silt.

From many of the timbered swamps the forests have been cut and the water drained to obtain farm land. Many of these swamps have peat soil, and after drainage dry out to great depths and are very susceptible to fire. Swamp drainage in this region has not usually been successful as an agricultural enterprise and has destroyed potential flood storage. Many swamps and overflow lands should be kept in forest for the double function of storing flood waters and producing such timber as they can grow. A third public service can often be rendered by them as breeding grounds for fish, waterfowl, and fur-bearing animals.

WOODLANDS OF THE CENTRAL FARMING REGION

From southern Minnesota and Wisconsin south through the central farming region there is a large aggregate of woodland, mainly in farm wood lots and in the rough and broken country that slopes down to the river channels. Studies made in Iowa showed that even small wood lots in a prairie region help decidedly in absorbing water into the soil. The wood-lot soils were found to contain more water than soils of similar character and slope on the open prairie or in cultivated fields. The forest cover on rough lands bordering streams, great and small, has in the aggregate an important bearing on erosion and stream flow.

These scattered woodlands of the central farming region are often in poor condition. They are apt to be thinned out by haphazard culling of timber, by overgrazing and trampling, and—particularly in the southern portion of the region—by frequent "woods burning." The agricultural character of this region precludes the extension of forests on any scale sufficient to materially influence the discharge of its streams. Yet every acre of existing woodland or of poor land that might advantageously be planted with trees can be made to contribute its mite to the solution of the problem we are dealing with.

RIVER BOTTOM FORESTS

Before the advent of agriculture, the forested overflow lands of the Mississippi and of some of its main tributaries were nature's storage reservoirs in times of flood. The floods, spreading far and wide through the tangled forests, lost some of the power which in later years has been concentrated between levees. The reclamation of the rich alluvial bottom lands was inevitable, but there is a question whether it may not have gone too far. Congress has appropriated funds for the purchase of about 260,000 acres of Mississippi bottom lands for the creation of the Upper Mississippi Wild Life and Fish Refuge. It is probable that in some places the value of overflow lands for storage, timber growing, game production, and recreation exceeds their value for agriculture. The feasibility of public acquisition of such lands for forests and wild-life refuges should be considered in the plan of flood control.

ROCKY MOUNTAIN FORESTS

The Missouri River, which with its numerous large tributaries is one of the principal feeders of the Mississippi, drains considerable portions of the eastern slopes of the Rocky Mountains. Fortunately much of the headwaters of these streams is embraced within national forests, which are managed not only for timber growing but for stream protection. Some further consolidations of the national holdings should be made, either by purchase or by exchanging Government timber for land. Here as elsewhere in rugged, mountainous country, public ownership is the surest safeguard against forest destruction and injury to watersheds.

On the western tributaries of the Mississippi, grasslands constitute a large part of the drainage, and the maintenance of their vegetative cover, as explained elsewhere, is a factor in flood control.

OZARK FORESTS

The Ozark Plateau and the Ouachita Mountains occupy an extensive stretch of country on the lower drainage of the Missouri and Arkansas Rivers and on the headwaters of the Ouachita, all important tributaries of the Mississippi. In the past, land in this region was cleared, farmed for a few years, and then abandoned and the process repeated somewhere else. The acreage treated in this fashion was large. The protection value of the remaining forests of the Ozarks has been materially reduced by lumbering, fire, and overgrazing, which have thinned out the timber and held down the ground cover. In the southern part of the region nearly a million acres of land are included within national forests, a portion of which has been purchased under the policy for protecting the headwaters of navigable streams.

These hills and mountains represent one of the key areas where forestry on a large scale can aid in reducing the Mississippi floods.

They form a natural forest region, containing but a small proportion of agricultural land. They are the only area within the drainage of the Missouri and Arkansas Rivers—aside from the extreme headwaters in the Rocky Mountains—where forest cover can materially influence the run-off, for the watersheds of these great rivers are primarily prairie and farm lands.

ALLEGHENY AND SOUTHERN APPALACHIAN FORESTS

The western slopes and plateaus of the Alleghenies and southern Appalachians contain the headwaters of such important tributaries of the Mississippi as the Ohio, the Tennessee, the Cumberland, and the Kentucky Rivers, which furnish to the great river nearly half its water supply. Among the forest regions influencing the run-off of the Mississippi Basin, the Appalachian and Allegheny Mountains are of primary importance.

Much of the soil of this region is close-textured and nonporous. Snowfall is light, and precipitation is often concentrated in torrential downpours. There is but little natural storage in the form of lakes and swamps. Water runs rapidly from the steep slopes, swiftly eroding cut-over or abandoned land. It is primarily the forest that holds the balance against the force of running water on mountain slopes. In such a region forest cover exerts its greatest influence on stream-flow and erosion. (Fig. 7.)

With the introduction of logging railroads, lumbering was extended into all but the very roughest parts of the mountains. The old-growth timber has now been reduced to one-third its original extent. Fire has still further impaired the cover of vegetation and leaf litter. In addition to denudation by logging and fire, there has been extensive clearing of slope lands for farms. Since about 1880 many hill farms have been abandoned, owing to the movement of the rural population to the towns and cities, and the land has largely been ruined by erosion.

These various forms of denudation have already caused irreparable damage. The Federal Government, recognizing the great importance of these mountain forests for stream protection as well as for timber growing, has gradually been purchasing lands for national forests under the Weeks Act. From Pennsylvania southward the Government has to date bought almost 2,000,000 acres in the Alleghenies and southern Appalachians. There is obvious need for more public forest ownership in a mountainous region bearing such a vital relation to the Mississippi River.

A FORESTRY PROGRAM FOR THE MISSISSIPPI BASIN

If forests are to contribute their utmost in any reasonable time toward the solution of the Mississippi flood problem, it is essential that forest protection, forest restoration, and public forest ownership be speeded up. It is short sighted to brush forestry aside on the ground that immediate flood relief is needed and that forest restoration takes time. Forestry is supplementary to immediate measures for flood relief—it is not a substitute for them. One of the functions of government is to take a long look ahead on problems of such profound significance to national welfare. Besides, the time element in forestry is easy to exaggerate. The reclamation of denuded lands by tree planting and the protection of existing forests can make themselves felt in better watershed conditions within a few years. Nature, if given half a chance, is prolific and energetic in restoring thinned-out and even denuded woodlands.

The main essentials of a forest program for the Mississippi Basin are as follows:

A large extension of public forest ownership, especially in the critically important mountainous and rough lands.

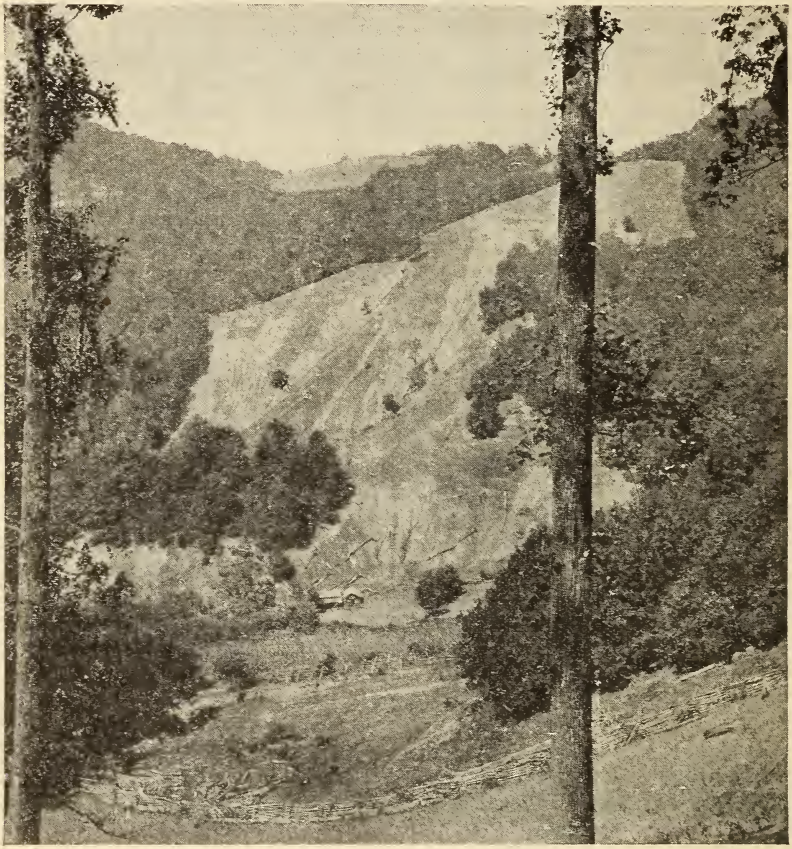

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FIG. 7.—In the conflict between running water and the soil of steep slopes, the forest holds the balance of power. Once this balance is destroyed, soil and water rush streamward. To prevent the destruction of mountain forests by logging or clearing, public ownership is essential. The most important tributaries of the Mississippi River have their headwaters in the Appalachian and Rocky Mountains, which should be kept forever forested

Thorough protection of all forests against fire.

More tree planting.

Public assistance in the better handling of woodlands, especially through research and educational work.

PUBLIC FOREST OWNERSHIP

Laws already exist under which land for national forests may be purchased anywhere in the drainages of navigable rivers. The Government has established and is extending national forests on watersheds within the Mississippi Basin. The present program of public forests should, however, be greatly enlarged and should be shared in by the States. The areas in the Mississippi Basin where protection forests are important, especially the Allegheny, Appalachian, and Ozark regions, should be accurately determined and an acquisition program formulated and apportioned by agreement between the Federal Government and the States. Public forests will pay good dividends in timber growing and in permanent forest industries; but wholly aside from these returns, public ownership is particularly urgent on lands subject to severe erosion and rapid run-off.

European experience has amply proved that mountain forests of high protective value do not safely lend themselves to private ownership, even under economic conditions favorable to timber growing. Public ownership of such forests is the only assured way to protect the headwaters of streams. The great bulk of the mountain forests in the Rockies and in the Sierra Nevada and Cascade Ranges of the Pacific States are in national forests. Probably 80 or 85 per cent of the main mountain ranges of the East should remain in forest; and to assure anywhere near this percentage, public forest ownership must be greatly enlarged.

Other types of protection forest should also come under public ownership. The denudation of swamp forests is often an invitation to ill-advised drainage of lands unsuited to agriculture but of great importance in water storage. Such swamps should be owned by the public. Overflow lands along the main river bottoms may also in many cases have a greater utility for water storage than for farming and may thus be better adapted to public than to private ownership. In order to reduce the silting of detention and storage reservoirs, their immediate watersheds should as far as possible be forested, a condition that can best be assured by public ownership.

FOREST-FIRE PROTECTION

Under the Clarke-McNary Act, the Federal Government cooperates with States and landowners in promoting better care of private forests, which constitute 80 per cent of our total forest area. The principal means employed is cooperative fire protection. The total cost of the protection of forest lands contemplated by this law is estimated at $10,000,000 annually. At present the three cooperating agencies are contributing only about $4,000,000, or two-fifths of the required amount. Over half of the 36 cooperating States are wholly or partly within the Mississippi Basin, but a large part of the forest land in the basin still receives little or no protection from recurring fires.

The rapid increase of cooperative fire protection under this law and its predecessor, the Weeks Act, has demonstrated during 16 years the practicability of Federal aid in forest protection as the first step toward better forest conditions. The chief needs in its further development are more adequate appropriations by the public agencies and the further extension of organized protection by the

States and owners. Of the private forests of the country, which constitute by far the larger part of all our forests, only about one-half receive any protection from fires.

There is no question that increased protection against fire will reflect itself rapidly in denser forest cover and in reduced erosion and run-off. Twenty years of protection in the western national forests has led to a marked improvement of large areas of mountain forests. Young trees have sprung up in the openings; and grass, herbaceous plants, and shrubs have become more vigorous and form a denser cover. Similar results have been achieved in many State and private forests.

TREE PLANTING

In the aggregate the farms of the Mississippi Basin contain an immense amount of poor, rough, or steep land, as well as denuded stream banks, that should be planted to forest. Farmers can seldom afford to do such planting unless they can obtain cheap planting stock. To meet this need the Clarke-McNary Act authorized Federal cooperation with the States in growing and distributing planting stock to farmers. All told the 32 cooperating States are producing about 60,000,000 trees a year, of which about half are set out on farms. To accomplish the purpose of this law there is need to increase greatly the size and capacity of State forest nurseries so that their output of trees can keep pace with the demand. There is need also for interesting more farmers in the benefits of forest planting and for extending this cooperative work to commercial timberlands. The present rate of forest planting, encouraging as it is, is but a snail's pace considered from the standpoint of the great areas of waste land in this country.

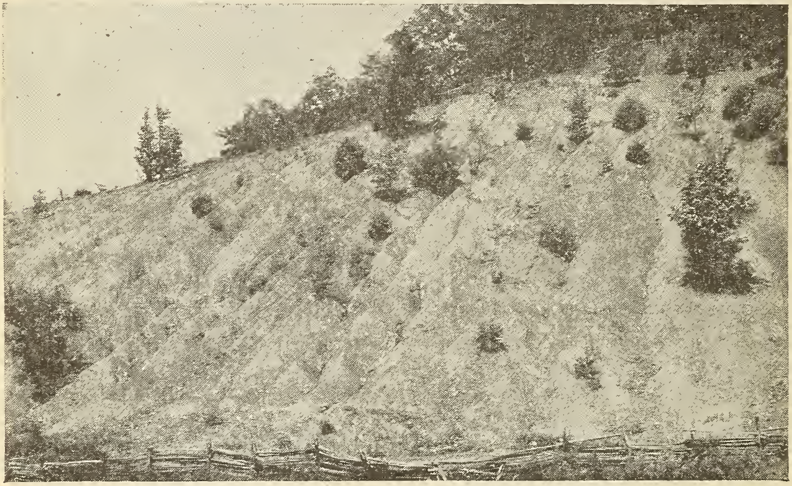

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FIG. 8.—There is much rough, steep land in farms that should be planted with trees to hold back soil and water. Tree planting will make idle forest land productive

PUBLIC ASSISTANCE IN BETTER HANDLING OF PRIVATE WOODLANDS

Many denuded lands must be planted if they are to have a forest cover. But most forests, unless completely denuded and burned out, will improve rapidly without artificial planting if given a chance. Recognizing this fact, the Clarke-McNary Act emphasized fire protection as the most important means of encouraging forest restoration. It provided also for cooperation with farmers in managing and improving woodlands. This cooperation should be extended to commercial forests, which are even more subject to deterioration and destruction than farm woodlands.

The entire Mississippi Basin is now included in the territory covered by Federal forest experiment stations. By furnishing basic knowledge on timber culture, these stations will be of great assistance in the management of both public and private forests, but there is need for more active effort by the Federal Government and the States to cooperate with private owners in getting this knowledge into effect.

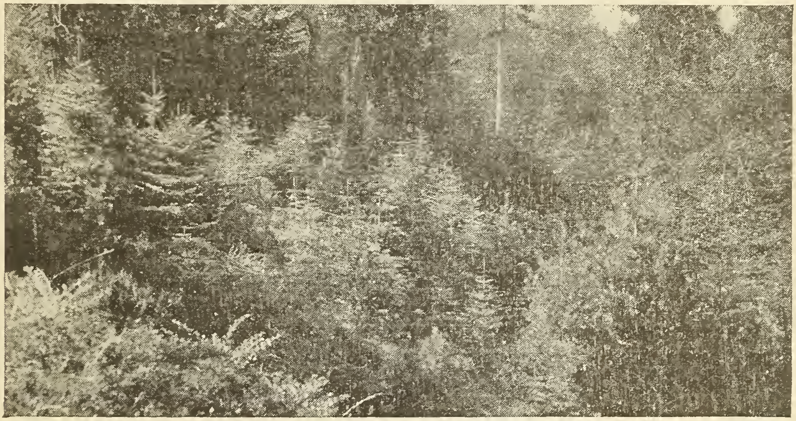

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FIG. 9.—Forest improvement does not require a lifetime. Good fire protection will rapidly mend most of our depleted forests. The national-forest land shown in the picture was logged 20 years ago. Conservative logging methods and subsequent protection have produced a sturdy young forest

SUMMARY

There are two chief lines of attack upon floods: First and most imperative, the construction of levees, storage reservoirs, and other engineering works to cope with water concentrated in great masses in main river channels; second and supplementary, the maintenance of dense vegetative cover, the terracing of farm lands, contour plowing, and other measures for keeping the land surface that is drained by the river system in condition to check run-off of rain water while it is spread harmlessly over the surface and before it attains mass and speed in stream channels.

Vigorous, dense vegetation (especially grass and forest) is one of the principal means of maintaining good surface conditions.

Of the various forms of vegetative cover, the well-kept forest is the best water and soil holder. The deep leaf litter and humus of the forest absorb large quantities of water into underground channels, whence it seeps slowly into springs and brooks. Even in winter the forest soil remains more absorptive because it freezes less freely and deeply. Forests prolong the melting of snow several weeks after it has disappeared from the open. Forests can not prevent high water after lengthy rainfall or sudden thaws; but even under such circumstances they diminish the volume and prolong the time of the flood run-off, thus tending to reduce its crest.

The forest, by slowing down run-off, by laying a thick mat of litter over the ground, and by binding the soil with a dense tangle of roots, also slows down erosion. The degree of erosion depends on the speed at which water runs off the surface and the extent to which it is allowed to work directly on the bare soil.

The beneficial effects of forest cover in retarding run-off and erosion have been established by authoritative observation and experiment in many parts of the world. Compared with a deep reservoir, the water-storing capacity of the forest is small. But in a great river basin the cumulative effect of vast areas of well-kept forest in holding back water from concentrating too rapidly in the one channel through which it must escape to the sea is of great importance in flood control. The forest is a shallow reservoir, but it makes up for its shallowness by the vastness of its extent.

Surface conditions in the Mississippi Basin have been profoundly altered by agriculture, lumbering, and grazing. Much of the sloping farm land has been cultivated without terracing or contour plowing, much of the grassland in the Great Plains region and elsewhere has been depleted by overgrazing, and much of the forest has been impaired or largely destroyed by careless logging and fire. From vast areas of improperly handled or denuded lands water has rushed more rapidly into the streams, carrying millions of tons of our richest topsoils, clogging river channels and reservoirs with silt, and causing violent and destructive floods.

Forests have been impaired or destroyed on many millions of acres of land entirely unsuited to agriculture. Forest rehabilitation on such lands is an essential means of restoring vigorous vegetative cover in the Mississippi Basin. Especially important are the forests on the Appalachian, Ozark, and Rocky Mountain tributaries of the Mississippi; for it is on mountain slopes that forest cover is most important. Forested swamps and river bottoms are also valuable for the storage of flood waters.

In order to get the maximum benefits of forest cover in the Mississippi Basin, it is essential that public ownership of forests, especially in the mountains and swamps, be greatly extended; that cooperation in forest-fire protection between the Federal Government, the States, and private owners be increased; and that the Government and States give more assistance to farmers and timberland owners in forest planting and better forest management.

Engineering works are a primary essential in flood control, but vigorous, well-kept forests will supplement and protect them. The two methods of control should be developed together, a river being treated as a unit from source to mouth.

The prudent use of forest land, like the prudent use of farm and grazing land, pays its own way, and the gain to flood control is a by-product without cost.

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